VAN NUYS. (T. C.)

REPORT ON THE WATERS

OF THE

INDIANAPOLIS

Water Works Co. and of White River

TOGETHER WITH

ANALYSES OF THE SAME,

MADE TO THE

BOARD OF HEALTH OF THE CITY OF INDIANAPOLIS.

BY

T. C. VAN NUYS, M. D.,

PROFESSOR OF CHEMISTRY, INDIANA STATE UNIVERSITY.

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REPORT AND ANALYSES

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Indianapolis Water Works Co. and of White River.

By T. C. VAN NUYS, M. D.

PROFESSOR OF CHEMISTRY, INDIANA STATE UNIVERSITY.

STATE UNIVERSITY LABORATORY,
BLOOMINGTON, INDIANA, January 31, 1881.

To the Board of Health of the City of Indianapolis:

GENTLEMEN:—At your request I have made analyses of the water supplied your city by the Water Works Company, and also of the water of White River, taken from different places. This work was carried on with the intention of ascertaining the quality of the water delivered by the Water Works Company, with especial reference to its use for drinking purposes.

The result of these analyses, together with other waters from various sources, and with such remarks as I have considered appropriate to elucidate the subject, I have the honor herewith to submit.

The numbers in the tables represent parts per 100,000 parts of the water. Dividing each number by 100 would give the number of grammes in one litre, or multiplying each number by seven, and moving the decimal point to the right one place, will give the number of grains in one imperial gallon.

TABLE NO I.—INDIANAPOLIS WATER.

PARTS PER 100,000.

Description.	Date.	Total Solids, Dried at 180° Cent.	Chlorine. Cl.	Nitric Acid, Anhyd. N_2O_5	Ammonia, NH_3	Organic matt'er before settling.	Organic matter after settling.	Lime. Ca O.	Magnesia. Mg O.	Degrees of Hardness. Temp'ry.	Perm'nt.	Total.
1. From a hydrant—the Water Works..........	April, 1880	Not est'd.	10 68	2.14	.003	Not est'd.	4.92	14.8	4.12	Not est'd.	Not est'd.	20.57
2. From a hydrant—the Water Works..........	June, 1880	47.30	18.90	1.74	.0038	Not est'd.	8.46	12.88	4.62	Not est'd.	Not est'd.	19.6
3. From the hydrant in Court House............	Sept., 1880	39.26	3.95	1.27	.0012	Not est'd.	5.53	11.8	4.569	10.6	3.8	14.4
4. From the hydrant in Court House	Dec., 1880	51.88	7.50	1.31	.012	Not est'd	4.74	Not est'd.	Not est'd.	11.	1.2	12.2
5. From well of Water Works........................	Oct., 1880	46.01	2.79	2.4	.02	Not est'd.	3.63	14.03	4.97	15.2	5.7	20.9
6. From well of Water Works........................	Dec., 1880	64.40	16.59	1.9	.015	Not est'd.	2.29	Not est'd.	Not est'd.	12.62	1.78	14.4
7. From White River, near Water Works......	Oct., 1880	28.63	0.418	0.357	.002	6.98	6.41	8.95	3.88	11.68	2.7	14.38
8. From White River, near Water Works......	Dec., 1880	Unfilter'd 58.99 Filtered. 27.41	0.369	1.1	.004	31.33	9.02	Not est'd.	Not est'd.	6.55	1.75	8.3
9. From White River, three miles above city..	Oct., 1880	26.92	0.206	0.306	.002	5.76	5.43	8.18	4.3	11.51	2.7	14.21
10. From White Riv., above bridge, Cold Spring	Dec., 1880	29.0	0.2	1.45	.005	9.96	9.25	Not est'd.	Not est'd.	6.45	1.65	8.1
11. From Murphy's well, on Schumann's farm.	Dec., 1880	34.0	0.0508	0.9	.003	Not est'd.	1.2	Not est'd.	Not est'd.	8.62	1 98	10.6

TABLE NO. II.—AVERAGE COMPOSITION OF VARIOUS WATERS.

PARTS PER 100,000.

Description.	Total Solid Matter.	Ammonia.	Nitric Acid Anhyd. N_2O_5.	Chlorine. (Cl).	Hardness. Temporary.	Hardness. Permanent.	Hardness. Total.	Number of Samples Analyzed.
Rain Water.	2.95	.029	.011	.22	....	....	.37	39
Norwegian block ice	0.47	.005	Not estim d	.05	....	....	Not estim d	1
Upland Surface Water.								
From Non-Calcareous Strata.								
From igneous rocks	5.15	.001	.007	1.13	.1	2.5	2.6	18
From Metamorphic, Cambrian, Silurian and Devonian Rocks	5.12	.002	.023	.92	.0	3.12	3.12	81
From Yoredale and Millstone Grits and the Coal Measures	8.75	.003	.038	1.05	.43	5.37	5.8	47
From Lower London Tertiaries and Bagshot Beds	8.40	.004	.026	2.06	.33	4.37	4.7	3
From Calcareous Strata.								
From Calcareous portions of Silurian and Devonian Rocks	13.71	.0	.080	1.20	1.45	9.25	10.7	3
From Mountain Limestone	17.07	.001	.042	1.24	7.05	8.75	15.8	7
From Calcareous portions of Coal Measures	22.79	.0 3	.061	1.52	4.93	10.37	15.3	26
From the Lias, New Red Sandstone, Conglomerate Sandstone and Magnesian Limestone	18.80	.002	.038	1.49	9.48	8.12	17.6	9
From the Oolites	17.46	.004		1.55	8.25	7.25	15.5	1
Deep Well Water.								
In Devonian Rocks and Millstone Grit	32.68	.044	1.131	2.70	10.95	10.75	21.7	7
In the Coal Measures	83.10	.005	.796	18.05	18.85	25.75	44.6	9
In Magnesian Limestone	61.14	.0	1.640	4.31	21.1	33.6	54.7	3
In New Red Sandstone	30.63	.003	2.760	2.94	9.2	13.1	22.3	28
In the Oolites	33.60	.022	2.406	2.69	17.2	8.5	25.7	5
In the Lias	70.98	.001	1.497	4.42	27.4	10.2	37.6	2
In the Hastings Sands, Greensands and Weald Clay	45.20	.016	.754	5.38	21.0	13.1	34.1	20
In the Chalk	36.88	.001	2.348	2.76	26.5	8.1	34.6	66
In the Chalk below London Clay	78.09	.048	.361	15.02	12.2	10.8	23.0	13
In Thanet Sand and Drift	53.84	.072	.446	6.32	18.0	9.5	27.5	4
Spring Water.								
From Granite and Gneiss Rocks	5.94	.001	.418	1.69	.5	3.2	3 7	8
From Silurian Rocks	12.33	.001	.685	1.84	1.9	6.6	8.5	15
From Devonian Rocks and Old Red Sandstone	25.06	.001	2.941	3.85	6.0	9.	15.	22
From Mountain Limestone	32.06	.001	.862	4 63	13.6	11.1	24.7	15

TABLE NO. II.—AVERAGE COMPOSITION OF VARIOUS WATERS. Continued.

PARTS PER 100,000.

DESCRIPTION.	Total Solid Matter.	Ammonia.	Nitric Acid Anhyd. (N_2O_5)	Chlorine. (Cl).	HARDNESS. Temporary.	HARDNESS. Permanent.	HARDNESS. Total.	Number of Samples Analyzed.
From Yoredale and Millstone Grits and the Coal Measures	21.91	.001	1.513	1.85	6.5	9.8	16.3	22
From Magnesian Limestone	66.52	.002	2.64	3.40	31.1	43.5	74.6	1
From New Red Sandstone	28.69	.001	1.270	2.19	10.2	13.3	23.5	15
From the Lias	36.41	.001	1.797	2.48	26.6	11.	37.6	7
From the Oolites	30.33	.001	1.547	1.55	22.8	7.7	30.5	35
From the Hastings Sand and the Greensands	30.05	.0	1.255	2.98	17.0	8.2	25.2	19
From the Chalk	29.84	.001	1.470	2.45	22.7	6.8	29.5	30
From the Fluvio-marine Drift and Gravel	61.32	.001	1.361	2.76	22.5	24.5	47.	10
LONDON WATER SUPPLY.								
Average of monthly analyses during ten years, 1868–1877. From the Thames	28.03	.0006	.808	1.73	....	....	25.5	600
From deep wells in Chalk	41.14	.0002	1.640	2.43	....	....	35.1	120
BIRMINGHAM WATER SUPPLY.								
Average of monthly analyses, 1876-1878	25.67	.002	.823	1.69	....	....	19.8	36
GLASGOW SUPPLY FROM LOCH KATRINE.								
Average of monthly analyses, March, 1877, to February, 1878	2.96	0	.015	.067	....	....	1.8	12
					SUSPENDED MATTER. Mineral.	SUSPENDED MATTER. Organic.	SUSPENDED MATTER. Total.	
SEWAGE.								
Fresh sewage; average from 16 water-closet towns	72.2	6.703	.011	10.66	24.18	20.51	44.69	50
Fresh sewerage; average from 15 midden towns	82.4	5.435	Not estim d	11.54	17.81	21.30	39.11	37

TABLE NO. III.—RIVER WATER.

PARTS PER 100,000.

RIVERS.	Date.	Total Solids.	Chlorine. Cl.	Nitric Acid Anhyd. $N_2 O_5$	Ammonia. $N_3 H_5$	Organic matter.	Lime. Ca O.	Magnesia. Mg O.	Hardness.	CHEMIST.
The Elbe, at Magdeburg		33.3	5.84	.33	.05	Not est'd.	11.7	2.5	1.52	Aehy.
The Elbe, at Hamburg	Aug., 1875	27.6	5.46	.0	Not est'd.	3.39	4.77	1.3	.66	Wibel.
The Elbe, at Hamburg	Dec., 1875	27.5	2.03	.05	Not est'd.	13.6	4.54	Trace.	.46	"
The Moldow		6.6	.35	.05	Not est'd.	.94	1.13	0.49	.18	Stœlba.
The Rhine, at Cologne	Oct., 1870	25.0	.25	Trace.	Not est'd.	5.2	7.49	2.05	Not est'd.	Vohl.
The Rhine, at Cologne	Nov., 1870	16.0	.99	Trace.	Not est'd.	6.4	3.58	0.43	Not est'd.	"
The Rhine, at Cologne	Jan., 1871	24.5	.37	Trace.	Not est'd.	.36	8.94	2.43	Not est'd.	Frostwetter.
The Saale, at Jena	July, 1872	24.5	.62	.11	Not est'd.	4.01	8.96	1.91	1.17	Reichardt.
The Saale, at Jena	April, 1873	12.5	.92	.2	Not est'd.	.93	1.8	0 36	.23	"
The Saale, at Jena	May, 1873	8.0	.97	.19	Not est'd.	3.88	3.36	0.73	.43	"
The Saale, at Jena	May, 1873	15.0	1.07	.22	Not est'd.	2.19	3.64	1.08	.52	"
The Hudson, at Albany	......, 1872	11.8	Not est'd.	Not est'd.	Not est'd.	.99	Not est'd.	Not est'd.	4.1	Chandler.
The Croton		9.8	Not est'd.	Not est'd.	Not est'd.	.95	Not est'd.	Not et'sd.	3.1	"
The Ohio, at Louisville	Sept., 1880	11.7	.63	.21	Trace.	10.8	3.16	0.78	4.2	Van Nuys.
The Ohio, at Evansville	Sept., 1880	18 6	.9	.33	.012	10.98	4.3	1.2	4.9	"

There is no method of estimating the exact quantity of organic matter in water. I employed the method of Schultze,* by which the quantity of oxygen is ascertained which combines with the organic matter in the water. For this purpose a solution of potassium permanganate of a certain strength is employed. It was suggested by an English chemist, Woods, that by multiplying the quantity of potassium permanganate, which is deoxodized by the organic matter by fire, or the quantity of oxygen liberated by twenty, the result would approximate the quantity of organic matter in the water. This method is employed in Germany and France almost to the exclusion of all others. Many of the English chemists, however, employ Frankland's and Armstrong's method by which the carbon, hydrogen and nitrogen of the organic matter are estimated. The quantity of organic matter found by this method is in every case too low, as volatile bodies pass off during the evaporation of the water. There are other objections to the employment of this method which can not be here considered.† To ascertain the relative quantity of the volatile organic matter in water of the Water Works sample, No. 3, I put 500 cubic centimetres of the water into a glass stoppered retort, having its neck directed slightly upward, the end bent downward, and connected with a Liebig's condenser, 300 cubic centimetres were distilled over in equal quantities.

The first distillate 100 c. c. required 0.0005719 grm. $K\,Mn\,O_4$ to oxidize the organic matter.

The second distillate 100 c. c. required 0.0004454 grm. $K\,Mn\,O_4$ to oxodize the organic matter.

The third distillate 100 c. c. required 0.0003855 grm. $K\,Mn\,O^4$ to oxidize the organic matter.

The ratios of the quantity of volatile organic matter in each distillate to 100 cubic centimetres of the water were—

First, 0.5 to 1.

Second, 0.4 to 1.

Third, 0.3 to 1.

This method of estimating the quantity of the volatile organic matter in water was lately proposed by Tiemann and Preusse,‡ but, as yet, it has been so estimated in very few cases; however, I found the ratios of the volatile organic matter to the total quantity by this method in water from the Ohio river, above Louisville, as follows:

First, 0.3 to 1.

Second, 0.24 to 1.

Third, 0.21 to 1.

And water taken from the river, above Evansville, yielded the following ratios:

First, 0.34 to 1.

Second, 0.28 to 1.

Third, 0.24 to 1.

And the first distillate of the water from one of the wells of the Indiana Reformatory Institution for Women, yielded the ratio 0.3 to 1 in this water. The

*Dingler's Journal 180-204.

†Journal of the Chemical Society, II, vol. 6, p. 152.

‡Berichte der Deutsch. Chem. Gesellschaft, B. 12, 1906.

other distillates were obtained under different conditions.* From these results, as far as a single analysis extends, Water No. 3, of Table I, contained more volatile organic matter than any of the water examined by this method.

The method employed in estimating ammonia was by use of Nessler's Reagent. Nitric acid was estimated by the method of Schloesing, modified by Reichardt and Tiemann.† The several samples of water were tested with meta-phenylenediamine (melting point 63° C.) for nitrous acid, but as the quantities found were very little greater than in rain-water exact estimations were not made. The lime and magnesia were estimated gravimetrically in all the numbers except Nos. 4, 6, 8, 10 and 11; in these the lime and its equivalent of magnesia were estimated by the use of a standard solution of soap. The degrees of hardness as given in the tables are *German*, that is one part of lime CaO by weight, or its equivalent of magnesia MgO, in 100,000 parts of water is known as one degree of hardness. The *permanent* degrees of hardness represent the lime and magnesia in the form of sulphates and chlorides, and hence are not precipitated by boiling the water. The relationship between the degrees of hardness adopted by Germany, England and France, are represented thus: 10 degrees of Germany equal 8 degrees of England, or 5.6 degrees of France.

MICROSCOPIC EXAMINATION.

I made a microscopic examination of several samples of water of the City Water Works, particularly Nos. 1, 2 and 3, and found numerous monads, rotifers, navicula, lanceolata, and various other infusoria. I did not find any bacteria. The samples of water of the Water Works, which were comparatively clear, deposited, after standing twenty-four hours, loose, floculent bodies, in which, by microscopic examination, various infusoria were found, and the floculent mass appeared partially organized, therefore, of animal or vegetable origin. It was for this reason that the suspended matter or sediment of the water of the Water Works, in some cases, was not estimated, as the division of the same after shaking the water was not perfect; however, to ascertain to a certain extent the quantity of the organic matter of these flakes in No. 5, the water, in a bottle of 965 cubic centimetres capacity, after the elapse of three days, was decanted off, except a small quantity containing the dark colored flakes; this was washed into a 250 cubic centimetre flask with the decanted water and filled to the mark. The quantity of organic matter was increased by these flakes from 3.63 to 10.19 per 100,000. parts of the water.

In order that the constitution of the water furnished by the Water Works Company, and that of White river, may be understood, I have introduced table No. II, showing the difference in constitution of water from various sources. These tables are from Frankland's Water Analysis. I have, however, changed the English into German degrees of hardness, and the "nitrogen, as nitrates and nitrites," is here given as nitric acid anhyd. N_2O_5. By examination of these analyses the fact that water varies greatly in constitution, according to its source, is at once perceived.

Table No. III gives the analyses of the water of a few rivers; in this table the fact that river water varies in constitution at different times and places is illustrated.

*American Practitioner, June, 1880.

†Zeitschrift, f. Analyt. Chemie. 9-24, und Berichte der Deutschen Chem. Gesellschaft VI, 1041.

By examination of these tables it will be observed that not all the solids of each water are estimated. To determine the quality of water for drinking purposes the bodies enumerated in the tables are the only ones required. In a *sanitary* analysis of water the estimation of lime and magnesia may be omitted, but I have estimated them, or determined the degrees of hardness, as this property of water is taken into account in the employment of water for technical purposes. Some of the bodies named in the tables are by no means injurious to health; the water of many mineral springs owe their curative propensities to the quantity of chlorides they contain, but the quantity of chlorine, for example, in river or well water serves as an index to its impregnation with sewage, contents of privy vaults, or the refuse of slaughter-houses, as these contain chlorides in considerable quantity. If the nitric acid or ammonia found in water in far greater quantity than is present in good water, it is not that these bodies are poisonous in such quantities that the water may properly be considered suspicious, but that they are the last products of the decomposition of organic bodies containing nitrogen, and, therefore, if the water contains no excess of organic matter they serve as an indication that, at a previous time, the water was rich in organic matter, which has been decomposed. Not all the nitrogen, however, of organic matter passes ultimately into nitric acid and ammonia, for the experiments of Reiset and Gilbert show conclusively that in the presence of alkaline carbonates about forty per cent. of nitrogen passes off free. Organic matter is sometimes found in great quantity, and nitric acid or ammonia in mere traces. This condition may be caused, first, by organic matter not being advanced in decomposition ; second, when the organic matter is vegetable in kind, and therefore not containing much nitrogen as a constituent; third, if water has been in contact with growing vegetables, the nitrogen of the nitric acid and ammonia may have been absorbed by them.

When urine, fæces and sewage pass into the soil, the organic constituents of them readily decompose by oxidation in the presence of low animal organizisms. Organic matter in all stages of decomposition—ammonium and potassium, phosphates and carbonates—are retained by the soil from solution, to a great extent; while the chlorides and nitrates of sodium, calcium and magnesium are not readily retained by the soil, but a solution of them passes into wells. Soil has not the property of retaining a great amount of organic matter and ammonia, and when it has become saturated, they, like the nitrates and chlorides held in solution, pass into wells; and hence the water in springs away from towns or villages is generally the best water for drinking purposes. When soil has become saturated with organic matter, there is deficiency of oxygen in the soil, and in consequence decomposition takes place slowly, and organic matter will be found in the water of the wells a very great length of time, and the precaution of cementing privy vaults would not qring about an immediate improvement of the water of the wells in the vicinity.

That not all soils have the same power of absorbing these bodies was proven by the experiments on the filtration of sewage by the Rivers Pollution Commissioners of England. The inorganic salts in water, which is at least suspicious, are not injurious to health, as the quantities of them in water are not sufficient to produce any effects; those of them which would, perhaps, produce an effect in great quantity are the nitrates and magnesium compounds, but they are comparatively in very small quantity, even in highly polluted water. There is no evidence that the death

rate is any greater in localities where hard water is used. To determine if water is good for drinking purposes, attention must be directed principally to the quantity of organic matter it contains, and to the microscopic examination. The quantities of chlorine, nitric acid, ammonia and solids must be taken into account, as they afford evidence of the contamination of the water.

So far the determination of the quality and exact quantity of the different solid products of the decomposition of animal and vegetable materials in water is impossible. There is, doubtless, a great number of them in polluted water, differing in kind in different waters. The decomposition of organic matter in water is greatly facilitated by the presence of living organisms—in fact, they are the principal agents in reducing complicated molecules of organic matter.

That the products of the decomposition of organic matter ever produce specific diseases is not probable, as no chemical compound is known which is capable of giving rise to a specific disease; those which have any effect at all give rise to general disorders of the nervous or nutritive system, known as toxic effects. If the question of the infection of impure water turns on the presence of living organisms, then why have not the greater number of waters of the earth become infected with the virus of typhoid fever, small-pox, cholera and other contagious diseases? Water found in nature perfectly free of some forms of animal or vegetable life is comparatively rare. Water containing organic matter forms a nidus for the development and proliferation of infusorial organisms of multitudinous forms. The germs or spores of these organisms are in the atmosphere, as shown by the researches of Pasteur, Cohen and others.

Subject a weak solution of albumen and a small quantity of soluble phosphate to the action of air at ordinary temperatures, organisms will be found in the fluid similar or identical in kind to those found in sewage or contents of privy vaults *

Water is an excellent solvent, and when it comes in contact with vegetable or animal matter, it takes some of it in solution, and hence water containing matter of animal or vegetable origin may be found where it would generally be supposed pure; for example, water of some deep wells, as those of Hamburg and Hanover, and from glaciers. The theory that impure water often becomes infected by the special virus of disease is generally accepted. The Rivers Pollution Commissioners of England devote forty-four pages in their sixth report to prove that the contagion of certain diseases is propogated by means of impure water. By a critical examination of the literature of this subject, it becomes evident that nine-tenths of the researches which have been made, or the conclusions drawn from them, do not have a true scientific basis. It is a very easy matter to assume that typhoid fever originated from water from a certain source, and it is still easier to connect cases by hypothetical links so as to form a whole chain of "evidence"

On the other hand, evidence that impure water generally does not become infected with the poisons of contagious diseases is not often brought to light. Many cities furnished with impure water are not, as a rule, visited by epidemics to a greater extent than those using a better quality of water. Before the establishment of the water works at Halle, Germany, well water was used for drinking purposes which

*Berichte der Deut. Chem. Gessellschaft IV, 170.

was polluted,* and the wells of Hamburg likewise furnish impure water. In this country the cities of Cincinnati, Louisville and Evansville are supplied with Ohio river water *without filtration*, yet in consequence we are not aware that these cities have been the abode of contagious diseases. Of 1,417 cases of typhoid fever treated in the Leipsic hospital in the space of twenty-four years, the majority originated in the parts of the city supplied with the best water.† A quantity of organic matter, nitric acid and chlorine found in water greater than is contained in the water of springs situated a distance from towns or other sources of organic impurity, prove beyond a doubt that the water contains sewage or soakage which deserves great attention. As the result of great experience in the examination of water from various sources, certain chemists have proposed the maximum quantity of each of these bodies which good water may contain. These limiting numbers, standards, or *grenzzahlen*, are here given.

The numbers represent parts in 100,000 parts of water.

CHEMIST.	Residue or Solids.	Organic Matter.	Nitric Acid Anhyd.	Chlorine.	Hardness. Total.
E. Reichardt.............	50	2.	0 4	0.2-0.8	18
Kubel and Tiemann.....	50	5	0.5–1.5	2.–3.	18–20
F. Wibel..................	50	5	0.5–2	3.5	18–20
F. Fischer................	50	4.	2.7	3.5	17
M. Pettenkoffer..........	....	5.	....	....	....

The Rivers Pollution Commissioners of England, appointed to investigate the subject of potable waters in general, and the water supply of London in particular, give as the result of their researches in their Sixth Report, 1868, a series of conclusions, some of which are as follows:

1. Any liquid which has not been subjected to perfect rest in subsidence ponds of sufficient size for a period of at least six hours, or which, having been so subjected to subsidence, contains in suspension more than one part by weight of dry organic matter in 100,000 parts by weight of the liquid; or which, not having been so subjected to subsidence, contains in suspension more than three parts by weight of dry mineral matter, or one part by weight of dry organic matter, in 100,000 parts by weight of the liquid.

2. Any liquid which shall exhibit by daylight a distinct color when a stratum of it one inch is placed in a white porcelain or earthenware dish.

3. Any liquid which contains more than one part chlorine in 100,000 parts.

The Vienna Water Commissioners, appointed to investigate into the water supply of the city of Vienna, came to certain conclusions regarding healthy (gesundes) water, as the result of their investigations. A translation of some of these from their report, made in 1864, is here given:

*Stohmann Muspratt's Tech. Chem., B. 4, S. 1746.

†Fluegge Zeitschrift, Biologie 13–502

1. Water must be clear, sparkling and colorless.

2. It must contain but a small quantity of solid materials and be entirely free of organized matter (infusoria.)

3. Of the alkaline earths (CaO, MgO), it must not contain more than 18 parts by weight in 100.000 parts by weight of the water.

4. It must contain but a small fractional part by weight of soluble salts, particularly the sulphates and nitrates.

5. The solids held in solution and the temperature of the water must vary within very narrow limits during the year.

6. It must be protected from contamination.

7. The above requirements are fulfilled in many cases by soft spring water, which alone is suitable for drinking purposes.

8. The industries require water having nearly the same properties.

9. Filtered river water, if at all times free of turbidity, will answer for technical purposes, but, on account of not fulfilling requirements 5 and 6, is not fit for drinking purposes.

10. To sprinkle or clean streets any water is suitable, providing it is odorless and does not contain a great amount of offensive materials.

THE WATER OF THE CITY WATER WORKS COMPANY FOR DRINKING PURPOSES.

Notwithstanding it is very doubtful if impure water ever becomes infected with the *germs* of disease, yet by the chemical and microscopic examination of water there can remain no doubt in regard to its purity or contamination and the proper course to pursue. To determine the quality of the water supplied by the Water Company it was desirable to ascertain, first, the quantity of the organic matter, chlorine, nitrates, etc., in the water of the well of the Water Works, or that drawn from the mains; second, the quantity of the above named substances in the water of the river near the Water Works; and, third, if the water of the river, near the Water Works, is similar in constitution to that above the city.

If we take cognizance of the proposed limiting numbers we must conclude that the water of the Water Works is suspicious. This is at once seen by examination of Table No. IV:

TABLE No. IV.

No. of Analyses.	CHEMISTS.	Solids dried at 180° C.	Chlorine.	Nitric Acid Anhyd. N_2O_5.	Organic Matter.	Degrees of Hardness.
	E. Reichardt	50.	0.2–0.8	0.4	2.	18.
	Kubel and Tiemann	50.	2.–3.	0.5–1.5	5.	18.–20.
	F. Wibel	50.	3 5	0.5–2.0	5.	18 –20.
	F. Fischer	....	3.5	2.7	4.	17.
	M. Pettenkoffer	....	....	....	5.	....
	DESCRIPTION.					
6	Water of Water Works	49.77	10.06	1.79	4.92	17.01
2	Water of White river near Water Works.	28.02	0.393	0.728	7.71	11.34
2	Water of White river near Water Works:	27.96	0.203	0.878	7.34	11.15

That five parts of organic matter in 100,000 parts of water, as given in the table by some of the chemists, is too high, there can be no doubt. In my judgment the limit should not exceed two. This conclusion is based on the fact that in water containing three parts organic matter in 100,000. parts when subjected to a moderate temperature in contact with air, numerous monads and algæ are developed, and, in order to prevent the formation of infusoria, water should not contain more than from 1.5 to 2 parts organic matter in 100,000 parts of the water. By refering to Table No. I, it will be observed that water from the hydrant in the court-house yard, sample No. 4, contained over twice the amount of organic matter than that of the well of the Water Works, No. 6, and, on the contrary, the latter contained over twice as much chlorine as the former.

When these results were obtained I concluded there was a mistake made as to the time of collecting the two samples. Inquiry was made and information was received that both samples were collected on the same day, December 10, and that in case of a fire water is taken directly from the river. If this be true the results are fully explained, as the excess of river water in the mains after a fire increased the quantity of organic matter above that in the water of the Water Works well, and the admixture diluting the 16.58 parts chlorine to 7.5 parts, as the water of White river contains much less chlorine than the water of the Water Works. If all the water in the well of the Water Works Company comes from the river it is

not improved to any great extent by the filtration. If part comes from the river, and by filtration is improved, then the water of the well from other sources is polluted; *for the amount of organic matter, chloride and nitric acid in the water of the Water Works well, proves beyond a doubt that there is sewage, contents of privy vaults, or effete materials of slaughter-houses dissolved in the water. It will be seen by referring to Table No. II that the chlorine in this water is in nearly as great a quantity as the average of it in sewage.* As far as the analyses of the water of White River are concerned they show that the water of this river contains that excess of organic matter, chlorides and nitrates, that the water of all rivers contain which flow through a cultivated country. Water from the middle of White River, opposite the Water Works, No. 8 of Table No. I, was very muddy and colored. The water, after shaking in a bottle and before settling, contained the enormous quantity of 31 33 parts of organic matter per 100,000 parts of the water, and yet there were but 1.1 parts nitric acid in that quantity of the water. The organic matter could not have been advanced in decomposition, as there were no growing vegetables with which the water could come in contact. River water varies greatly in the quantity of bodies held in solution, particularly organic matter. On account of the limited number of analyses of the water of White River, this is not shown in Table No. I. Reichardt estimated the total organic matter, nitric acid and chlorine, in the water of the river Saale, taken from the river above the city of Jena. Twelve estimations were made, the water in each case was taken from the river about the first day of each month for twelve consecutive months. The variations in quantity of these bodies were as follows:

Total solids, 8 to 31.2; difference, 23.2; average of 12 estimations 18.8
Organic matter, 0.93 to 4.10; difference, 3 17; average of 12 estimations...... 2.87
Nitric acid, 0.11 to 0.65; difference, 0.54; average of 12 estimations............. 0.21
Chlorine, 0.57 to 2.17; difference, 1.60; average of 12 estimations................. 1.25

Reichardt conducted a great number of analyses of the water of the Spring Muehlthal, near Jena, which in part supplies the city with water. The following are his results:

Total solids, 29 5 to 47; difference, 17.5; average of all estimations...............37.
Organic matter, 0.16 to 1.26; difference, 1.10; average of all estimations...... 0.57
Nitric acid, 0 11 to 0.54; difference, 0.43; average of all estimations.............. 0.25
Chlorine, 0.52 to 1.15; difference, 0.63; average of all estimations.................. 0.77

Reference has been made to some of Reichardt's work as illustrating very well the properties of good river water, on one hand, and those of good spring water on the other. By these results, river water is shown to be unfit for drinking purposes, as the variations in composition are according to the amount of rain-fall, for when the stage of water is high decaying vegetables and animal matter are dissolved by the water, and its tributaries carry into it all manner of impurities, to say nothing of manufacturers of starch, soap, oil, dyes, etc., which may discharge their materials of waste into the river.

The limiting numbers, of themselves, are of little value in the determination of the quality of water; but taking into account the variations of composition, based on estimations made at different times, they become of great value. The results of

the six analyses of the water of the Water Works show that the variations in its composition are great, proving conclusively that the water is contaminated:

Total solids, 36.26 to 51.88; difference, 12.65; average of the six analyses 49.77
Organic matter, 2.29 to 8 46; difference, 6.17; average of the six analyses...... 4.92
Nitric acid, 1.27 to 2.40; difference, 1.13; average of the six analyses.. .... 1.79
Chlorine, 2.79 to 18.90; difference, 15.11; average of the six analyses............10.06

A single analysis of water is of little value in determining its quality for drinking purposes, unless the results show a considerable excess of organic matter, nitric acid, chlorine, etc.

THE FUTURE WATER SUPPLY OF THE CITY OF INDIANAPOLIS.

The water of White River can, by *proper filtration*, be improved sufficiently for drinking purposes. There is, however, difference of opinion on the effectiveness of filtration of river water. The conclusions, Nos. 6, 7 and 9, of the Vienna Water Commissioners shut out the use of filtered river water for drinking purposes; and the Rivers Pollution Commissioners, in their sixth report, consider water that contains any animal substances beyond redemption, so far as filtration is concerned. In regard to the London water supply, from the Thames, they report:

1. The Thames, above the intake of the respective water companies, receives the sewage from a large number of towns and other inhabited places, the washings of a large area of highly cultivated land, and the filthy discharges from many industrial processes and manufactures.

2. The water is used for bathing, for the washing of sheep and cattle, and of dirty linen, and the putrid carcasses of animals float upon its surface. It is the common water-way for a large amount of polluting matter, much of which is at times dangerous to the health of persons who use even the filtered water for dietetic purposes.

3. In time of flood, a large proportion, both of suspended and dissolved filth, is conveyed down to the intakes of the metropolitan water companies; and in ordinary weather a considerable proportion of the soluble organic matter of sewage, discharged into the river and its tributaries, likewise makes its way down to the works of the water companies, and is still present in the water distribnted by them in London.

4. The water is, nevertheless, when efficiently filtered, free from any offensive taste or odor.

5. Notwithstanding the application of partial remedies for sewage pollution at Banbury, Eaton, and Windsor, and the greater care exercised by most of the companies in the storage and filtration of the water, the organic pollution contains in the Thames water delivered in London, though subject to fluctuation from the greater or less prevalence of floods, does not diminish.

6. There is no hope of this disgusting state of the river being so far remedied as to prevent the admixture of animal and other offensive matters with the filtered Thames water as delivered in the metropolis.

7. The temperature of the water drawn from the companies' mains is liable to excessive fluctuations, being near the freezing point in winter, and so warm in summer as to render the water vapid and unpalatable.

8. We therefore recommend that the Thames should, as early as possible, be abandoned as a source of water for domestic use, and that the sanction of your Majesty's Government be, in future, withheld from all schemes involving the expenditure of more capital for the supply of Thames water to London. That the water of the Thames is not purified sufficiently by the several water companies, is occasioned by the filters being too small for quantity of water filtered, sand too coarse or too fine, or the rate of flow of the water through the filters too rapid. It must be taken to account that the seven metropolitan water companies, taking water from the Thames or Lea, have in view the making of their business as lucrative as possible. We have demonstration of the fact that polluted water can be purified by filtration. In the water furnished Altona, a city below Hamburg, on the Elbe river, the Water Works Company take water from Blankenese, eight miles below Hamburg. The water of the river at this point contains all the sewage, etc., of Hamburg. and by filtration this water loses nearly all its organic matter, and all its infusorial organisms

Samuelson* experimented several years on the filtration of polluted waters, and discovered many important facts regarding the process. For example, the maximum rate of flow of the water through a filter differs in different waters, and sand must be of certain quality as to size, etc.

A second source of water supply may be obtained from White River by *natural filtration.* For the employment of this process the banks of the river must be low and composed largely of sand. By a system of canals† of stone, earthen ware, or iron, in the sand several feet below the surface water, is conveyed into cemented reservoirs, which are necessarily deep, and in order to prevent the water from freezing in winter, or becoming warm in summer, they are arched over. By this mode of filtration the city of Lyons is supplied with water from the banks of the Rhone, Toulouse from the Garonne, and Genoa from the Scrivia. Water obtained by this mode of filtration differs greatly in constitution from river water, and, unlike the latter, is of low temperature and constant in quality. From the analysis of the water of Murphy's well, on Schumann's farm, Table No. I, the water of White river, by natural filtration, may be the most practical source of water supply of Indianapolis. Although river water can be purified by filtration, yet the want of skill required in the arrangement of filters, choice of sand, or rate of flow of water through the filter, results in the delivery of polluted water. Consequently some cities, located on rivers, have their water supply from springs. Frankfort on the Main receives water from the springs of Vogelsberg and Spessart; Vienna from the High Mountain Springs (Hochgebirgsquellen); and, although the collection mains of the water works of Dresden, are in a stratum of sand adjoining the Elbe, yet the water which they receive does not come from the river. Of eighty cities in Germany, supplied with water by water works, only twelve receive

* Filtration des Flusswassers von Kirkwood, uebersetzt von Samuelson.

†These canals or mains may be perforated above and surrounded by coarse gravel and bowlders—they may be arranged on different plans.

water direct from rivers; whereas, according to Reichardt, of twenty water works, from 1849-65, twelve employed river water; and by the same authority we learn that in 1871, of eight water works projected only two took river water; and of the fifteen water works projected in 1873, not one employed river water. Eleven of the twelve cities of Germany at present receiving river water, direct from rivers, have the same filtered.

It is apparent that river water, even when subjected to subsidence and filtration, is a last resort as a source of supply. Permit me, in conclusion, to remark that the question of the future water supply of the city of Indianapolis, is one that should not be decided in haste.

To Prof. S. B. Wylie, assistant in the Department of Chemistry, and Mr. I. N. Corr, an advanced student in Chemistry, I am greatly indebted for valuable assistance rendered in carrying on the analysis herein reported.

Respectfully yours,

T. C. VAN NUYS.